SPECIFICATION

Docket No.: GP-39-2/P1359

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN, that we, Richard W. DeLange and Ghazi J. Hashem, both citizens of the United States of America and residing in Kingwood, Harris County, Texas; and Houston, Harris County, Texas, respectively, have invented new and useful improvements in a

THREADED CONNECTION
FOR INTERNALLY CLAD PIPE

of which the following is a specification:

CERTIFICATE OF EXPRESS MAILING

I, Jan C. Lipscomb, hereby certify that this correspondence and all referenced enclosures are being deposited by me with the United States Postal Service as Express Mail with Receipt No. EL010849445US an envelope addressed to Box Patent Application, Assistant Commissioner for Patents, Washington, DC 20231, on June 28, 2001.

By: Jan C. Lipscomb

THREADED CONNECTION FOR INTERNALLY CLAD PIPE

Related Applications

This application is a continuation-in-part of U.S. Application Serial No. 09/030,459, filed February 25, 1998.

Background of the Invention

Field of the Invention

The present invention relates to threaded pipe connections and, more particularly, to a corrosion-resistant threaded connection assemblies for use with clad pipe such as can be used as oil and gas well tubing and casing, piping in chemical and other plants, oil and gas pipelines, and the like.

Description of the Prior Art

There are numerous instances where piping and pipelines are used for transporting fluids that are highly corrosive to materials such as carbon steel from which such pipe and pipelines are typically made. In particular, in the production of oil and gas, there is a growing need for corrosion-resistant alloy pipe, e.g., tubing, because of the continuing increase in the drilling of oil and gas wells into pay zones that produce highly corrosive fluids. To overcome the corrosion problems, and as well known to those skilled in the art, it is common to use lined steel pipe, which liners may be made of plastic, stainless steel, or other corrosion-resistant materials.

A typical multiple-walled composite pipe, e.g., a lined steel pipe, is a dual or double-walled pipe in which the inner wall is a liner tube made of a corrosion-resistant material, e.g., stainless steel, or some other corrosion-resistant material (metal alloy) that serves as a conductor for the corrosive fluid, and an outer wall or pipe that is designed to provide strength to withstand the internal pressures of the corrosive fluid, as well as external forces such as external pressure, mechanical loading, etc.; e.g., carbon steel that may be corrosion-prone.

Obviously, particularly in the case of tubing or casing, there are limitations on the length of such double-walled pipes due to conditions to which the pipes are subjected on site. Thus, in the case of tubing or casing strings and in the production of oil and gas,

each joint of pipe is usually about 30-40 feet long while the tubing or casing string itself may be thousands of feet long. Accordingly, and as is well known in making up such tubing or casing strings, successive joints of tubing/casing are connected together using couplings until the desired length of string is achieved.

Typically, in these multiple-walled composite pipes, the inner tube or liner made of the corrosion-resistant material does a highly effective job of protecting the corrosion-prone outer tube or pipe. Indeed, methods of successively internally cladding corrosion prone pipe with a corrosion-resistant material are well known to those skilled in the art. The problem is not with the clad pipe, but rather where successive joints of the clad pipe are adjoined to one another by means of a coupling. For many years, the goal has been to create a "holiday-free" interface at the junction of the clad pipe and the coupling. It serves no purpose to connect clad pipe utilizing a coupling that is subject to corrosion since such a connection will sooner or later fail because the coupling will fail.

The prior art is replete with pipe couplings and assemblies ostensibly designed to overcome the problem of eliminating corrosive attack at the junction of the pipe and the coupling. However, insofar as is known to Applicants, none of these solutions have been readily embraced by the oil and gas industry, either because of cost factors, failures caused by corrosion, or lack of sufficient structural integrity at the pipe/coupling juncture.

In U.S. Patent No. 5,282,652, there is disclosed a corrosion-resistant pipe coupling structure comprising a tubular coupling member having axially opposite ends thereof. Internal screw threads form boxes that engage male screw threads forming pins provided on the axially opposing end parts of two pipes to be connected, the internal surface of each of the pipes being resistant to corrosive fluids. An intermediate annular projection is provided on the inner surface of the coupling member and directed radially inwardly thereof to be abuttingly interposed between the opposing end parts of the pipes. The structure is characterized in that the intermediate annular projection is made of a corrosion-resistant material, at least in a radially intermost part thereof.

U.S. Patent No. 4,026,583 also discloses corrosion-resistant tubing or casing for use in the oil and gas industry.

Summary of the Invention

It is therefore an object of the present invention to provide a corrosion-resistant threaded connection assembly.

Another object of the present invention is to provide a workpiece for use in making a corrosion-resistant, threaded tubular member.

Still a further object of the present invention is to provide a method of forming a workpiece for use in making a corrosion-resistant threaded tubular member.

Yet another object of the present invention is to provide a corrosion-resistant threaded tubular member.

Still a further object of the present invention is to provide a method of forming a corrosion-resistant tubular member.

The above and other objects of the present invention will become apparent from the drawings, the description, and the claims.

In one embodiment, the present invention provides a corrosion-resistant threaded connection assembly comprising a first tubular member having an outer tube of corrosion-prone material, e.g., carbon steel, and an inner tubular lining of corrosion-resistant material, e.g., stainless steel or some other corrosion-resistant metal alloy, the first tubular member including a first pin connection. The outer tube has a first end and a second end. The first pin connection comprises a nose portion formed on a first ring of corrosion-resistant material--e.g.--a metal alloy, secured to the first end of the outer tube of corrosion-prone material, thereby forming a first annular securing locus. The first ring of corrosion-resistant material defines a first annular, axially facing end surface and a first radially outwardly facing, annularly extending thread-free pin shoulder formed on the corrosion-resistant ring. A first axially extending, externally threaded portion providing male threads is formed at least partially on said outer tube and extends axially inwardly of the pin shoulder and first end surface, the first securing locus being disposed intermediate the first end surface and the end of the externally threaded portion distal the first end surface. The assembly further includes a second tubular member comprising a coupling having a first end and a second end, the coupling having a first box connection formed in the first end and a second box connection formed in the second end. The coupling further includes an internally disposed annularly extending section of corrosion-resistant material disposed intermediate the first and second ends of the coupling. Each

of the box connections comprises a radially inwardly facing, annularly extending box shoulder formed on the section of corrosion-resistant material. Each of the box connections further includes an axially extending, internally threaded portion providing female threads complementary to the male threads of the first pin connection and extending axially outwardly of the thread-free box shoulder. The pin and box shoulders are sized and configured such that when respective ones of said first pin connections are threadedly received in the first and second box connections, the pin and box shoulders are in metal-to-metal sealing engagement.

In yet another embodiment of the present invention, there is provided a workpiece for use in making a corrosion-resistant threaded tubular member. The workpiece includes an outer metal tube of corrosion-prone material having a first end, a second end, and an inner surface. A first ring of corrosion-resistant material is secured to the first end of the metal tube, a first annular securing locus being formed between the first ring and the first end of the metal tube. An inner metal tubular lining of corrosion-resistant material is disposed in the outer tube, the metal lining having a first end, a second end, and an outer surface, the outer surface of said lining overlying said inner surface of said tube and said first annular securing locus, the first end of said lining being secured to the first ring.

In yet another embodiment of the present invention, there is provided a method of forming a workpiece for use in making a corrosion-resistant threaded tubular member. In the method, a metal tube of corrosion-prone material is provided, the metal tube having a first end and a second end. A first ring of corrosion-resistant material is permanently secured or bonded to the first end of the metal tube to form a first annular securing locus between the first ring and the first end of the metal tube. The method further includes providing a metal tubular liner of corrosion-resistant material, the liner having a first end and a second end and disposing the liner in the tube, the liner overlying the first annular securing locus and being secured to the first ring.

Yet a further embodiment of the present invention comprises a corrosion-resistant, externally threaded tubular member. The externally threaded tubular member includes an outer metal tube of corrosion-prone material having a first end, a second end, and an inner surface. A first ring of corrosion-resistant material is secured to the first end of the metal tube. A first annular securing locus is formed between the first ring and the

first end of the metal tube. An inner, metal tubular lining of corrosion-resistant material is disposed in the outer tube, the metal lining having a first end, a second end, and an outer surface. The outer surface of the lining overlies the inner surface of the outer metal tube and the first annular securing locus, the first end of the lining being secured to the first ring. The first ring defines an annular, axially facing end surface and can have a first radially outwardly facing, annularly extending threadfree pin shoulder formed externally on the first ring. A first axially extending, externally threaded portion providing male threads is formed at least partially on the tube and extends axially inwardly of the first end surface. The first securing locus is disposed intermediate the first end surface and the end of the first externally threaded portion distal the first end surface.

In still another embodiment of the present invention, there is provided a method of forming a corrosion-resistant, externally threaded tubular member. In the method, a metal tube of corrosion-prone material is provided, the metal tube having a first end and a second end. The method furthers includes securing a first ring of corrosion-resistant material to the first end of the metal tube by permanently bonding the first ring to the first end of the metal tube to form a first annular securing locus between the first ring and the first end of the metal tube, the first ring facing a first end surface. The method further includes providing a metal tubular liner of corrosion-resistant material, the liner having a first end and a second end, and disposing the liner in the tube, the liner overlying the first annular securing locus and being secured to the first ring. The method further includes forming a first axially extending, externally threaded portion providing male threads, the first threaded portion extending axially inwardly of the first end surface and being at least partially formed on the metal tube, the first securing locus being disposed intermediate the first end surface and the end of said first externally threaded portion distal said first end surface, and optionally forming a first radially outwardly facing, annularly extending, threadfree shoulder on the first ring.

Brief Description of the Drawings

Fig. 1 is a half-sectional, elevational view of one embodiment of the assembly of the present invention;

Fig. 2 is an enlarged fragmentary portion of Fig. 1 showing in particular the engagement between the corrosion-resistant materials on the pin ends and the coupling;

Fig. 3 is a view similar to Fig. 2 showing the incorporation of a deformable seal ring in the assembly;

Figs. 4-6 are half-sectional, elevational views showing sequentially how one embodiment of the coupling of the present invention is formed;

Figs. 7-9 are half-sectional, elevational views showing how the threaded pin members of the assembly of the present invention are formed;

Fig. 10 is a fragmentary, half-sectional, elevational view showing one pin connection made up to one of the boxes in the coupling and showing engagement of the nose of the pin connection with a torque or makeup shoulder formed in the coupling;

Fig. 11 is a view similar to Fig. 10 showing the connection of Fig. 10 placed in tension such as would be encountered in a tubing or casing string such as would be used in an oil or gas well;

Fig. 12 is a fragmentary, half-sectional, elevational view showing another embodiment of the assembly of the present invention;

Fig. 13 is a fragmentary, half-sectional, elevational view showing another embodiment of the assembly of the present invention;

Fig. 14 is a view similar to Fig. 1 showing another embodiment of the assembly of the present invention;

Fig. 15 is a view similar to Fig. 1 showing another embodiment of the assembly of the present invention;

Fig. 16 is a fragmentary, half-sectional, elevational view showing another embodiment of the assembly of the present invention;

Fig. 17 is a half-sectional, elevational view showing a workpiece for making an externally threaded, corrosion-resistant tubular member in accordance with the present invention;

Fig. 18 is a fragmentary, half-sectional, elevational view showing one method of securing the inner corrosion-resistant liner to the corrosion-resistant ring to provide a workpiece, such as shown in Fig. 17;

Fig. 19 is a fragmentary, half-sectional, elevational view showing an externally threaded, corrosion-resistant tubular member made from the workpiece of Fig. 18;

Fig. 20 is view similar to Fig. 18 showing another method of securing the corrosion-resistant liner to the corrosion-resistant ring to make the workpiece of Fig. 17;

Fig. 21 is a fragmentary, half-sectional, elevational view showing an externally threaded, corrosion-resistant tubular member made from the workpiece of Fig. 20;

Fig. 22 is fragmentary, half-sectional, elevational view of another embodiment of the externally threaded, corrosion-resistant tubular member of the present invention;

Fig. 23 is a fragmentary, half-sectional, elevational view of another embodiment of the externally threaded, corrosion-resistant tubular member of the present invention; and

Fig. 24 is a fragmentary, half-sectional, elevational view of another embodiment of the externally threaded, corrosion-resistant tubular member of the present invention.

Description of the Preferred Embodiments

With reference to Figs. 1 and 2, there is shown a corrosion-resistant threaded connection assembly according to the present invention comprising a coupling, shown generally as 10, and described more fully hereafter, and first and second tubular members or pipes, which could be tubing or casing, shown generally as 12 with pin connections (pins) shown generally as 12a described more fully hereafter.

Coupling 10 comprises a tubular member 14 having a first box end 16 with tapered, female threads 18 and a second box end 20 having tapered female threads 22. Coupling 10 further includes an annular insert, shown generally as 24, of corrosion-resistant material that is secure internally of tubular member 14 by ways well known to those skilled in the art and discussed hereinafter. Insert 24 defines a first annularly extending conical thread-free box shoulder 26 and a second, annularly extending conical thread-free box shoulder 28. Insert 24 also forms an annular, radially inwardly projecting rib 30, rib 30 defining a first annular axially facing abutment 32 and a second annular, axially facing abutment 34.

Pipes 12 are substantially the same in construction and comprise an outer tube 36 of a corrosion-prone material, e.g., carbon steel or the like, and an inner metal lining or liner of corrosion-resistant material 38, lining 38 being secured to tube 36 by methods well known to those skilled in the art and described more fully hereinafter. It will be understood that lining 38 extends for the full length of pipe 12. As noted, each of pipes 12 form a first pin connection 12a having a nose portion formed of a ring 40 of corrosion-resistant material that is secured as by welding, as at 42, to tube 36, weld 42 forming an

annular weld locus between ring 42 and pipe 36. Ring 40 further includes a radially outwardly facing, annularly extending, conical, thread-free pin shoulder 44 for a purpose hereinafter described. Ring 40 also defines an axially facing, annularly extending end surface 46. As can be seen, particularly with reference to Fig. 2, rib 30 is of a dovetail configuration and end surfaces 46 on pins 12a are complementarily shaped. Each of pins 12a further includes a tapered male threaded portion 48 extending axially outwardly of pin shoulder 44. It can thus be seen that when pipes 12 are received in coupling 10 such that threads 48 on first pin 12a and threads 18 in first box end 16 and threads 48 on second pin 12a and threads 22 in second box end 20 are threaded together, and when end surfaces 34 on pins 12a engage abutments 32 and 34 to the desired makeup torque, forming "torque shoulders," the coupling 10 and the pins 12a will be in metal-to-metal sealing engagement. To this end, shoulders 26 and 44 with respect to first box end 16 and 28 and 44 with respect to second box end 20 are sized and configured such that when the pins 12a are threadedly received in the coupling 10, shoulders 26 and 44 in the first box end form an interference, metal-to-metal seal, and likewise shoulders 28 and 44 in the second box end form an interference, metal-to-metal seal. It will thus be appreciated that a "holiday-free" zone has been created at the juncture of the pipes 12 and the coupling 10 in that in order for any corrosion-prone material to be exposed to corrosive fluids passing through pipes 12 and coupling 10, such fluid must leak past the metal-to-metal seals formed by the engaged shoulders 26, 44, and 28, 44. In other words, the flowing corrosive fluid sees only corrosion-resistant material, not only internally of the pipes 12 with respect to the lining 38, but also with respect to any of the components making up the threaded connection comprised of coupling 10 and the pins 12a formed on pipes 12. As noted above, it is important that the juncture of the pipes 12 and the coupling 10 be constructed in such a fashion that any corrosive fluids passing through pipes 12 and coupling 10 be prevented from contacting any corrosion-prone material making up either pipes 12 or coupling 10. Thus, for example, whatever technique is used to secure ring 40 to pipe 12 must eliminate the possibility that there will be any corrosion-prone material disposed between lining 38 and ring 40 so that corrosive fluids can pass the juncture of lining 38 and ring 40 and get between lining 38 and tube 36. Accordingly, any method or technique used to secure ring 40 to pipes 12 will ensure that corrosion-resistant material spans any securing zone or locus between lining 38 and ring

40. This can be accomplished, for example, by using corrosion-resistant weld or brazing material. In yet another technique, lining 38, prior to the time that ring 40 is attached to pipes 12, can be flared over the end of outer pipe 36 adjacent the ID and corrosion-resistant weld material used to form the securing locus between the ring 40 and lining 38 to ensure that there is no portion of corrosion-prone material forming pin 12a that is exposed to any corrosive fluid.

While as described above ring 40 is secured to pipe 12 by means of welding--e.g., friction welding--it will be appreciated that other techniques for securing ring 40 to pipe 12 can be used, i.e., the annular securing locus between ring 40 and pipes 12 can be formed by welding, brazing, or, in certain cases, with special adhesives that are not affected by any corrosive fluids. For example, the securing locus might be formed by an annular wafer of material disposed between ring 40 and the end of pipe 12, which can, by means of proper treatment, fuses, or form with ring 40 and pipe 12 some other kind of fluid-tight bond, e.g., an intramolecular bond, between ring 40 and pipe 12. As noted hereafter, ring 40, when the connection is fully made up--i.e., when coupling 10 and first and second pins 12a are threadedly received therein--is under compressive loading, which greatly expands the types of securing techniques and securing agents that can be employed to form the securing locus. While the securing locus, in this case described as weld 42, is simply shown as a line joint between ring 40, on the one hand, and pipe 36 and lining 38, on the other hand, it will be appreciated that this is for simplicity only and that the securing locus, e.g., the weld locus, can have a significant axial thickness depending upon the securing agent and/or securing technique employed. Another securing technique that can be advantageously employed in securing the corrosion-resistant ring 40 to the pipe 12 can be accomplished by a technique that employs temperatures below which there is no effect on the metallurgical properties of the ring and the pipe. Whatever the nature of the securing locus and/or the method used to achieve it, there must result a liner (38), pin (36), ring (40) juncture that is corrosion-resistant.

While as described above there is only pin connection 12a on pipe 12, it will be appreciated that in the usual case a similar, second pin connection will be formed on the opposite end of pipe 12 such that successive lengths of pipe 12 can be adjoined to one another using a coupling, such as coupling 10.

With respect to Fig. 3, there is shown a modification of the embodiment shown in Figs. 1 and 2, wherein there are incorporated deformable seal rings 50 and 52, rings 50 and 52 being disposed in recesses 54 and 56 formed in first and second box ends, respectively. Seal rings 50 and 52 further ensure that any corrosive fluids that leak past the metal-to-metal seals will be prevented from contacting the interengaged threaded portions of the connection, which, as can be seen for the most part, are formed of corrosion-prone material.

Attention is now directed to Figs. 4-6, which show how a coupling for use in the assembly of the present invention can be constructed. Disposed in a tubular blank 60 is a corrosion-resistant, annular section 62 of corrosion-resistant material, annular section 62 generally being secured interiorly of tubular blank 60 by methods discussed hereinafter. Tubular blank 60 and corrosion-resistant section 62 are then machined, as shown in Fig. 5, to provide an unthreaded coupling preform 10a having an unthreaded corrosion-resistant insert preform 24a. Following threading, in the well-known manner, and as shown in Fig. 6, one achieves coupling 10 comprised of threaded tubular member 14 containing insert 24, identical to that shown in Fig. 1. While Figs. 4-6 show construction of a coupling that is a composite, i.e., formed of the tubular blank 60 of a corrosion-prone material and an annular section 62 of corrosion-resistant material, it will be appreciated that the operations depicted in Figs. 4-6 could be carried out to produce a coupling that is made entirely of corrosion-resistant material rather than the composite shown in Figs. 4-6. In other words, the tubular blank 60 and an annular section 62 could comprise a monolith of corrosion-resistant material. Nonetheless, essentially the same machining/threading operations shown in Figs. 4-6 would be conducted on the monolith.

Figs. 7, 8, and 9 show a typical sequence of steps in forming the pin connections 12a of pipe 12. A tubular blank 64 formed of an outer tube of corrosion-prone material such as carbon steel 66 and an inner corrosion-resistant lining 38 is welded as by friction-welding or some other suitable welding technique, to an annular corrosion-resistant ring 68, the weld being indicated at 70. Following the securing of ring 68 to tubular blank 64, machining is conducted to provide a pin connection preform 64a, which results, as shown, in tube 66, being formed into a tapered tube 66a. Additionally, corrosion-resistant ring 68 is machined to provide a pin nose preform 68a, thread-free shoulder 44

being formed in such machining step. Lastly pin preform 64a is threaded to form pin connection 12a.

Figs. 10 and 12 demonstrate two conditions of the assembly of the present invention, Fig. 10 showing the assembly made up, i.e., the pin connections threadedly received in the coupling, and in a "relaxed" condition, i.e., there being no axial forces acting on the assembly other than as imposed by the interengaged threads. Fig. 11 shows the connection of Fig. 10 in a typical condition such as would be experienced in an oil and gas well when a "string" of tubing or casing employing the threaded connection of the present invention is employed to connect successive joints of tubing, casing, or the like. As can be seen by the arrows A and B, the tension forces indicated by arrows A and B are transmitted from one pipe joint 12 to the successive pipe joint 12 through the coupling 10 by virtue of the interengaged threads 48 on the pins 12a with the threads 18, 22 in the coupling 10. This tension loading, if sufficiently high enough, will separate the abutment 32 formed on the rib 30 from the end surface 46 formed on the first pin connection 12a. Such separation is shown in exaggerated form in Fig. 11, it being understood that a like separation would occur between abutment 34 and end surface 46 formed on the second pin connection 12a. However, even though such separation of the torque shoulders may occur, the connection remains sealed because of the metal-to-metal, interference seal between shoulders 26 and 44. It will be understood that while only the first box end 16 is being described, a like situation applies with respect to the second box end 20.

As can be seen from Figs. 10 and 11, the weld zone 42 is disposed intermediate threads formed on the pin 12a such that at least the last thread closest the nose of the pin 12a is formed primarily at least of corrosion-resistant material forming ring 40. Positioning the securing or weld zone or locus between engaged threads helps to maintain the loading in tension on the assembly across that zone or locus to a minimum. While the embodiment of Fig. 11 shows the weld locus 42 being disposed generally between the first thread on the pin nose 12a and the next adjacent thread, Fig. 13 shows a condition where the weld locus has been moved further away from the nose of pin 12a, i.e., further into the threaded area. Thus, with reference to Fig. 13, ring 40a, shown as having a larger axial length than ring 40, is secured to pipe 36 by a weld zone 42a disposed generally in the area of the third and fourth threads on pin 12b, i.e., the weld

zone is further up in the threaded zone. In general, it is preferred that the securing zone, e.g., weld zone, be disposed in the threaded area such that it lies between adjacent engaged threads since, as noted, this tends to maintain the loading in tension on the assembly across the securing zone to a minimum. Moving the securing zone further into the threaded area will generally mean that the axial length of the ring 40a is increased; e.g., compare the axial length of ring 48 with the axial length of ring 40. This is clearly desirable since such added axial length has the advantage that if the nose of the pin formed by the corrosion-resistant ring 40 or 40a is damaged, there is sufficient material remaining such that, with proper machining and threading, a new pin nose 12a can be formed without the necessity of having to add an entirely new corrosion-resistant ring.

With reference to Fig. 12, there is shown another embodiment of the assembly of the present invention wherein corrosion-resistant ring 40b is secured to pin 12c at a weld zone 42b, which is on the pin nose side of the first thread of pin connection 12c, i.e., the weld zone essentially lies in the thread-free zone and, more particularly, approximately at the start of the thread-free pin flank 44a. It will be apparent that in the embodiment shown in Fig. 12 with the weld zone out of the threaded portion of the connection, once the connector is made up, the weld zone 42b is placed in compression. In essence, ring 40b is essentially in a neutral state because the coupling 10, which transmits the tension between successive joints of pipe 12, has no effect on ring 40b in the sense that it is not exerting a significant pulling force on ring 40b. It will be appreciated that one of the features of the present invention is the fact that for all intents and purposes, the corrosion-resistant ring, e.g., ring 40, forming the nose of the pin is essentially placed in compression when the assembly comprising the coupling 10 and the pipes 12 are made up to full makeup torque. This clearly minimizes the chances that the corrosion-resistant ring will be separated from the pipe 12 since, for all intents and purposes, the forces acting on the corrosion-resistant ring are tending to force those two members together. This unique construction places the corrosion-resistant rings under compressive loading, and as noted above, provides an expanded variety of securing techniques and agents, e.g., welding, brazing, etc., that can be used to secure the corrosion-resistant rings to the pipes.

Reference is now made to Fig. 14, which shows another embodiment of the connection assembly of the present invention. The assembly shown in Fig. 14, indicated

generally as 90, is what is referred to in the industry as a stepped thread design. The coupling, shown generally as 92, comprises a tubular member 94 having a corrosion-resistant, annular insert 96 disposed generally centrally therein. There are thus defined first and second box connections 98 and 100, respectively. First box connection 98 is provided with a first tapered, axially extending, internally threaded female portion 102 and a second axially extending, internally threaded female portion 104, threaded portions 102 and 104 being axially spaced from one another and separated by a makeup or torque shoulder 74. As in the case of box connection 98, box connection 100 is likewise provided with a first axially extending, internally threaded female portion 108 and a second, axially extending internally threaded female portion 110, threaded sections 108 and 110 being displaced axially from one another and separated by a torque or makeup shoulder 112. So-called stepped threads as described above having makeup or torque shoulders separating the axially spaced stepped threaded portions are well known and are shown, for example, in U.S. Patent Nos. 4,161,332 and 4,192,533 and patents referenced therein, all of which are incorporated herein by reference for all purposes. Insert 99 is provided with a first annular, radially inwardly extending surface 114 in box 98 and a second annular, radially inwardly extending sealing surface 116 in box 100.

The assembly shown in Fig. 14, as those described above, further includes an elongate tubular member 118 comprising an outer pipe 120 of corrosion-prone material and an inner lining 122 of corrosion-resistant material. As in the manner described above with respect to ring 40 and pipe 36, pipe 120 is secured to an annular ring 124 of corrosion-resistant material, ring 124 being provided with an annularly extending, radially outwardly facing sealing surface 126. Tubular member 118 forms a pin connection 128 formed by a first threaded male portion 130 and a second threaded male portion 132, threaded male portions 130 and 132 being axially spaced from one another, a first annular, axially facing makeup shoulder 134 being formed between threaded male portions 130 and 132. It will thus be apparent that when first and second pin connections 128 are received in boxes 98 and 100, respectively, and makeup shoulders 106 and 134, on the one hand, and makeup shoulders 134 and 112, on the other hand, are engaged to the desired torque, a metal-to-metal seal will be formed between annular sealing surfaces 114 and 126 in box connection 98 and between sealing surfaces 116 and 126 in box connection 100. Once again, it will be seen that any corrosive fluids being carried

through the connection assembly will "see" nothing but corrosion-resistant material inasmuch as the corrosion-prone portions of the assembly are protected from attack by the corrosive fluid by virtue of the corrosion-resistant lining 122, the corrosion-resistant insert 96, and the corrosion-resistant rings 124.

With reference to Fig. 15, there is shown a slightly modified embodiment of the assembly shown in 14, the embodiment shown in 15 differing from that shown in Fig. 14 only in the fact that the entire coupling 92a is formed of corrosion-resistant material rather than being formed, as coupling 92, of a corrosion-prone tubular member 94 and an insert of corrosion-resistant material 96.

With reference now to Fig. 16, there is shown yet another embodiment of the connection assembly of the present invention. In the embodiment shown in Fig. 16, coupling 10c is similar to coupling 10 with the exception that insert 24b, rather than having an annular rib such as rib 30, shown in Figs. 1-3, is provided with a rib 30b, which is not undercut and which rather is provided with abutment surfaces 32a and 34a, which are axially facing and which lie generally in planes perpendicular to the axis passing axially through the connection assembly. As can also be seen, abutment surfaces 32a and 34a do not form torque or makeup shoulders. In this regard, annular ring 40b is formed with an end surface 46a, which is annular and axially facing and which generally lies in a plane perpendicular to the long axis of the connection assembly. It will be seen that rather than being in contact, surfaces 24b and 46a with respect to the first box connection and surfaces 34a and 46a with respect to the second box connection are not in engagement, leaving a gap. However, since annular seal surfaces 26 and 44 are in metal-to-metal interference or sealing engagement, all corrosion-prone portions of the connection assembly are protected from attack by corrosive fluids flowing through the connection assembly.

Except for the embodiment shown in Fig. 16, most of the embodiments of the present invention have been described with reference to an internal shoulder formed between the noses of the pins 12a and a rib similar to rib 30 formed in the coupling 10. Fig. 16 demonstrates that such shouldering, while clearly desirable, is not a necessary limitation of the threaded connection of the present invention. Indeed, the threaded connection of the present invention can be constructed without annular ribs similar to rib 40, i.e., in such a manner that there is no portion of the coupling 10 that protrudes radially

inwardly between the innermost ends of the pins 12a. Nonetheless, any such connection would have the metal-to-metal radial seals such as are formed by engaged shoulders 26, 44 and 28, 44, for example. It will also be appreciated by those skilled in the art that torque or makeup shoulders that are external to the connection assembly can be employed. Indeed, as shown in Fig. 14, in the case of a stepped thread design, such makeup or torque shoulders can be formed intermediate axially spaced stepped threaded portions. Whatever form or position of torque or makeup shoulder is employed, a feature of the present invention is the provision for metal-to-metal sealing between a radially outwardly facing, annularly extending surface or shoulder on the pin or male member and a radially inwardly facing, annularly extending surface or shoulder in the box connection formed in the coupling. Although the metal-to-metal seals are shown as being formed by the engagement of frustoconical surfaces, it will be appreciated that the invention is not so limited and that other complementarily shaped surfaces that can be forced into metal-to-metal sealing engagement can be employed.

In the embodiments shown heretofore, the ends of the corrosion-resistant lining are generally co-terminus with the ends of the corrosion-prone pipe, and in such cases the corrosion-resistant ring is secured to the liner-pipe assembly. Although an effective threaded connection can be made in this manner, one disadvantage of this approach is that the annular securing locus--e.g., the annular weld zone--between the ring and the pipe is exposed to any fluid internally of the connection. Should the weld zone have any flaws, corrosive material in the pipe could then attack the connection through the weld zone, potentially leading to failure. Additionally, with the securing loci (weld zones) exposed to any fluids in the connection, there is always a possibility that during welding, if that is the manner in which the ring is affixed to the tube, some of the corrosion-prone material that makes up the outer pipe could encroach into the securing locus with the same result as discussed above. The problems regarding potential contact of the securing locus (weld zone) with corrosive fluids can be virtually totally eliminated using the embodiments hereinafter described with respect to Figs. 17-21.

With reference first to Fig. 17, there is shown an outer pipe body 200 having first and second ends 202 and 204, respectively, and an inner liner 206 having first and second ends 208 and 210. To form workpiece W, a first corrosion-resistant ring 212 would be permanently secured or bonded to the first end 202 of pipe 200 by some suitable

technique discussed above--e.g., friction welding, first ring 212 forming a first end surface 213. A second corrosion-resistant ring 214 would be permanently secured or bonded to the second end 204 of pipe 200 by some like technique, second ring 214 forming a second end surface 215. Accordingly, one would have a blank comprised of pipe 200, first corrosion-resistant ring 212 permanently attached to the first end 202 of pipe 200, and a second corrosion ring 214 permanently attached to the second end 204 of pipe 200. It will be apparent that there thus will be formed a first annular securing locus 216 between ring 212 and first end 202 of pipe 200 and a second annular securing locus 218 formed between second ring 214 and second end 204 of pipe 200. Again, while the securing loci 260 and 218 are shown as lines, it will be apparent that depending upon the method of securing the rings 212, 214 to pipe 200, the annular securing loci 216, 218 will have varying axial thicknesses. To now complete workpiece W, liner 206 is now disposed in the blank formed of pipe 200 and rings 212, 214. It will be seen that by this technique, the outer surface of the liner 206, as well as overlying the inner surface of the pipe 200, will also overlie the annular securing loci 216, 218. Workpiece W shown in Fig. 17 would have the rings 212, 214 secured to the liner 206 by some suitable technique, described more fully hereinafter. However, it will be recognized that once the liner 206 is secured to rings 212, 214, there would be no necessity to bond the outer surface of liner 206 to the inner surface of pipe 200, since liner 206 would be secured to rings 212, 214 by some technique that also formed an annular seal between liner 206 and ring 212 on the one hand, and liner 206 and ring 214 on the other hand. Thus, any corrosive fluid could not enter into any annulus that might be present between liner 206 and pipe 200. It will be appreciated that in certain cases, a corrosive-resistant ring will be secured to only one end of the outer pipe, the other end being attached to a flange or the like. In this case, the liner would be attached to the flange or the pipe to prevent ingress of fluids between the liner and pipe.

With reference now to Figs. 18 and 20, there are shown various techniques for securing liner 206 to rings 212 and 214. With reference first to Fig. 18, ring 212 could be provided with an internal, conical chamfer 220, leaving a void between liner 206 and ring 212 at the end 208 of liner 206. This void could then be filled in with a suitable corrosion-resistant weld material to provide an annular weld or seal 222 that would secure liner 206 to ring 212 and also prevent the ingress of any fluid into any annulus

between liner 206 and pipe 200. In like fashion, liner 206 could be secured to ring 214, if desired.

With reference to Fig. 20, liner 206 is seen as having a first end 208a, which, instead of being co-terminus with first end surface 213 of ring 212, terminates short of end surface 213. In this case, weld material could be used to form an annular, generally cylindrical weld buildup 224 that extends from first end 208a of liner 206 to first end surface 213 of first ring 212. In addition to securing liner 206 to ring 212, the annular weld 224 would also form a fluid-tight seal to prevent any ingress of fluid into any annulus that existed between pipe 200 and liner 206. In like fashion, liner 206 could be secured to ring 214.

Figs. 19 and 21 show corrosion-resistant, threaded tubular connections formed from the workpiece embodiments depicted in Figs. 18 and 20, respectively. With respect first to Fig. 19, it can be seen that tapered, male threads 226, which bridge first annular securing zone 216, are formed by machining ring 212 and the adjacent section of pipe 200 in the well-known fashion. As can be seen, following the machining to form threads 226, the threaded tubular connection TC would have a remaining portion of weld indicated as 222a that secured liner 206 to ring 212a. In like fashion, a pin connection could be formed on the other end of pipe 200, to which ring 214 is secured.

With reference to Fig. 21, a pin connection similar to that shown in Fig. 19 could be formed from the workpiece shown in Fig. 20 basically in the manner described above with respect to the pin connection shown in Fig. 19 and formed from the workpiece shown in Fig. 18. However, in this case, as can be seen, an annular, generally cylindrical weld formation 224a would remain, weld formation 224a serving to secure liner 206 to ring 212a, as well as providing a fluid-tight seal as described above with respect to the embodiment of Fig. 19. In like manner, a virtually identical pin connection could be formed at the second end of pipe 200, to which ring 214 is secured, thereby providing a corrosion-resistant tubular connection having external or pin threads on each end.

It can be seen that in the embodiments of Figs. 19 and 21, the pin connections can be machined to form annularly extending threadfree shoulders 228 on rings 212 and 212b.

It will be appreciated that it is not necessary that both ends of the workpiece W be formed into threaded pin connections as shown in Figs. 20 and 21. For example, it

may be desirable to form a threaded connection on only one end, the other end being secured to a flange or fitted to some other component. Additionally, as noted, it will be apparent that it may be desirable that only one end of the pipe 200 be provided with a corrosion-resistant ring--e.g., ring 212--since the other end could be secured, for example, to some corrosion-resistant flange or the like.

With reference now to Figs. 22-24, there are shown other embodiments of the first tubular member--i.e., the tubular member on which the pin connection is formed. With reference first to Fig. 22, the tubular connection, indicated generally as TC, is comprised of an outer metal tube 300, a ring 302, and a tubular corrosion-resistant metal liner 304. The securing locus between outer tube 300 and ring 302 is indicated as 306, which, as noted above, can be accomplished by friction welding or other securing methods. As seen, tubular liner 304 has a portion 308 that extends beyond the end 310 of outer tube 300. However, as can be seen, the end of tubular liner 304 does not extend to end surface 312 of ring 302. Rather, it terminates short of end surface 312 and is secured to ring 302 by means of a weld 314 of corrosion-resistant material. As in the case with the other pin connections, the threaded connection shown in Fig. 22 is provided with external male threads 316.

With reference now to Fig. 23, the threaded connection shown generally as TC is comprised of an outer metal tube 400, a corrosion-resistant ring 402, and a metal tubular corrosion-resistant liner 404. As can be seen, metal liner 404 terminates short of the end of metal tube 400. Ring 402 is provided with a tubular cylindrical flange 406 that extends axially from ring 402 distal end surface 408. Flange 406 has an OD that is generally the same as the ID of tube 400 and is received in the first end 401 of tube 400. As can be seen, there is an annular weld 410 of corrosion-resistant material securing the end of tubular liner 404 to flange 406. Also, ring 402 is secured to outer tube 400 by annular weld zone 412, which preferably is of corrosion-resistant material.

With reference now to Fig. 24, the tubular connection shown generally as TC is comprised of an outer tube 500, a ring of corrosion-resistant material 502 having an end surface 504, and a corrosion-resistant metal tubular liner 506. Ring 502 is secured to tube 500 via an annular weld zone 508 that, preferably, is of corrosion-resistant material. As can be seen, ring 502 is provided with a counterbore 510 that has an axially inward, annularly extending abutment surface 512. It can also be seen that tubular liner 506 has

a portion 514 that extends beyond the end of outer tube 500 and overlies weld zone 508. The portion 514 of tubular liner 506 is received in the counterbore 510 and is secured to ring 502 by means of a corrosion-resistant, annular weld zone 516 that essentially fills any space between abutment surface 512 and the end of tubular liner 506 received in counterbore 510.

It will be apparent that many modifications of the above invention not expressly described can be made. For example, and as shown, torque shoulders are not necessarily needed. Additionally, deformable seal rings can be used in the embodiments shown in Figs. 14 and 15 and various thread forms can be used in any of the embodiments. It will be appreciated that the corrosion-resistant materials of the present invention can take many forms. Thus, for example, various liner compositions may be employed, depending upon the corrosiveness of the fluid being handled. For example, high alloy materials such as Hastelloy C, Iconel 625 may be used for extremely aggressive and corrosive environments, whereas lesser alloy-containing steels such as 26 Cr-1-Mo, 28 Cr-4-Mo, 17-4-PH, and Carpenter 450 can be used for less aggressive environments such as those containing chlorides, wet carbon dioxide, or the like. It will also be appreciated that the radial thickness of the corrosion-resistant liner can vary depending upon the material employed and the degree of corrosiveness of the fluids being handled.

Bonding between the corrosion-prone pipe and the corrosion-resistant liner and/or between the coupling and corrosion-resistant insert can be achieved by numerous methods well known to those skilled in the art and as exemplified in U.S. Patent No. 4,026,583, incorporated herein by reference for all purposes. Accordingly, the bond between the pipe and the liner may be a braze bond, which, for example, may be achieved by heating of the liner to brazing temperatures, in which case the liner outer surface would have a liquefying temperature substantially lower than that of the corrosion-prone pipe. As an example, the liner could include a metallic outer coating such as copper, which liquefies at a relatively low temperature and, which once liquified, would bond the corrosion-resistant liner to the corrosion-prone pipe. In still another manner, the bond between the liner and the corrosion-resistant pipe can be achieved by internally pressuring the liner to cause it to weld to the corrosion-prone pipe, the material of the liner diffusing into the metal of the corrosion-prone pipe. Such pressure may be created by an explosion within the liner or by a pressurizing liquid contained within the liner, as

more fully disclosed in U.S. Patent No. 4,026,583. The liner and/or insert may also be shrink-fitted into the pipe and/or coupling, respectively.

In yet another manner of lining the corrosion-prone pipe with the corrosion-resistant liner, a metallurgical bond between the pipe and liner can be achieved in a process described in an article entitled "Seamet: the Economical Clad Pipework Solution," *Stainless Steel World*, Jan./Feb. 1997. In this process, a composite billet is formed from an outer host billet of carbon steel and a corrosion-resistant preform that is radially expanded and axially upset inside the hollow host billet. The composite billet is then extruded to produce a seamless pipe lined with the corrosion-resistant material. During the extrusion process, a metallurgical bond is created to the extent that, for example, chromium, forming part of the corrosion-resistant material, migrates into the host carbon steel layer. The bond that results has the strength and ductility equivalent to that of individual component alloys. It will be appreciated that clad pipe made in this fashion is not suitable for the embodiments of the present invention shown in Figs. 17-21 because of the fact that with respect to those embodiments it is necessary that the corrosion-resistant rings be affixed to the corrosion-prone pipe prior to the corrosion-resistant liner's or lining's being disposed in the corrosion-prone pipe. Nonetheless, even with respect to the embodiments shown in Figs. 17-21, it may be desirable to bond the liner to the pipe, metallurgically or by other techniques, described above.

In all cases, it will be appreciated that however the liner or lining is disposed in, secured to, or formed with the outer tube--e.g., by extrusion of a composite billet--the outer surface of the liner will overlie the complete inner surface of the pipe, except as shown in alternative embodiments, described above.

The term "disposing," or similar term, used with reference to the liner in the pipe is intended to include any means or method of providing a lining of corrosion-resistant material that overlies the inner surface of the outer pipe to prevent such inner surface from being contacted by fluids carried by the lined pipe.

The foregoing description and examples illustrate selected embodiments of the present invention. In light thereof, variations and modifications will be suggested to one skilled in the art, all of which are in the spirit and purview of this invention.